EFFECTS OF CLIMATE VARIABILITY ON MAIZE PRODUCTION IN KENYA

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DECLARATION

This research paper is my original work and has never been presented for a degree award in any other University.

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This research paper has been submitted for examination with my approval as University Supervisor.

Signature……………………………………Date…………………………………

PROF. ANTHONY WAMBUGU.

DEDICATION

To my loving family for being there for me in time of need.

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First, I am greatly indebted to my supervisor, Prof. Antony Wambugu whose insights, instructions and comments made this work, a success.

Secondly, I thank my lecturers and the entire staff of the School of Economics, University of Nairobi for the role they played during my study, and towards this project.

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Last but not least, Glory be to God.

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ACRONYMS

FAO	Food and Agriculture Organization
GDP	Gross Domestic Product
KIPPRA	Kenya Institute of Public Policy Research and Analysis
KNBS	Kenya National Bureau of Statistics
VECM	Vector Error Correction Model

ABSTRACT

Agriculture is the mainstay of many Kenyans. Over 50 percent of farmers in Kenya produce maize crop for both subsistence and commercial purposes. Currently, maize crop production is declining which has led to a deficit of Kenya's staple food. Despite evidence that a decline in maize production is partly attributed to variability in climate, these revelations in the Kenyan case is still scarce. Therefore, the study aimed to investigate the effects of climate change on maize production in Kenya and how such effects differ across regions. A production function approach as modified by Ochieng et al. (2016) was adopted to determine the effect of climate change on maize productivity in Kenya. System Generalized Methods of Moments (GMM), Fixed and Random effects model as well as Pooled Ordinary Least Squares were applied on a three-year data set (2004, 2007, and 2010) from the Tegemeo Institute. It was found that first, climate variability, in temperature negatively affected maize production in Kenya. The results also show that maize farmers in the Coastal, Eastern, Nyanza, and Rift Valley Provinces produce more maize as compared to those from Central province. The econometric results also indicate that increases in agricultural assets owned by households, age of the head of the household and household size increases maize production. Further, male-headed households were able to produce more maize in comparison to female-headed households. The results further established that household maize production reduced with acreage devoted to maize production. From these findings, it is suggested that households in Kenya should undertake various adaptation strategies to cushion themselves from the negative impacts associated with variation of climate in order to improve maize yields. Further, the Kenyan government should also adopt policy interventions that can reduce effects of global warming.

CHAPTER ONE

INTRODUCTION

1.0 Background

Food and Agriculture Organization (FAO) (2013), estimates that 2.5 billion people in the world who live in rural areas derive their economic living from agriculture. In Sub-Saharan Africa, agriculture employs 62 percent of the population (Livingstone et al., 2011.), accounts for 90 percent of all production in some countries, 80 percent of all these coming from smallholder farms (Wiggins, 2009). Barrios et al. (2008) also argue that in Sub-Saharan African economies, agriculture is a critical contributor to the economic growth process. It contributes to an estimated 40 percent of the real GDP and employs over half of the total laborforce (Barrios et al., 2008).

In Kenya, the agricultural sector plays a crucial role in the economy similar to those highlighted in Sub-Saharan African economies. Agriculture sector is taken as a leading sector in the Kenyan economy as it contributes to an estimated 27 percent to real GDP (KIPPRA, 2017) employs an estimated 70 percent of the laborforce in the rural areas, accounts for an approximately 52 percent of the export earnings as well as a crucial enabler of food security (Republic of Kenya, 2017).

Notwithstanding the highlighted role of the agriculture sector in the Kenyan economy, the performance of Kenya's agricultural sector has been unsteadying over the years. For example, according to the data obtained from economic surveys published by KNBS, in 2010, agriculture sector contribution to GDP declined to 21.4 percent from 23.5 percent in 2009. Further, in 2016 the share of agriculture in GDP rose to 32.6 percent from 30.4 percent in 2015. Apart from the unsteady agriculture production levels in the economy, in recent years Kenya has experienced episodes of food deficits, particularly on maize. It is argued that the deficits are majorly attributed to the vulnerability of Kenya's agriculture to climate changes since extreme climatic scenarios for instance droughts and floods tend to be more regular (KIPPRA, 2017).

Despite the acknowledgement of the effects of variation in climate on crop yields around policy circles, few studies have been undertaken in developing economies to empirically establish the role of variability in climate on agricultural productivity despite these economies being more vulnerable to climate variability (Sarker et al., 2012). Earlier studies on this subject have largely been undertaken in the developed economies (Mendelsohn et al., 1994). In Kenya, except for the study by Kabubo-Mariara and Karanja (2007) on the role of changes in climate on the household revenue from agricultural production, Ochieng et al. (2016) on climate variability on tea and maize revenue, Siahi, et al., (2018) on the effect of changes in climate on maize productivity by adopting Vector Error Correction Model, no study to the authors knowledge has exclusively studied the linkage between climate variability and maize production from microeconomic perspective in Kenya together with examining the regional differences on this subject. To this end, this paper analyzed the effects of variation in climate on the maize productivity in Kenya. The study narrows its examination on maize productivity because, since Kenya's independence in 1963, maize is a key staple food for the country and that investigation on how climate variability affects its productivity warrants an empirical investigation.

1.1 An Overview of Maize Production in Kenya

Maize is an important crop in Kenya's agricultural economy. According to data obtained from FAOSTAT, in 2011-2013, an estimated 40 percent of all land under crop cultivation was occupied by maize. Evidence from the agriculture ministry also indicates that maize accounts for approximately 50 percent of all staples grown in the country. But despite the Maize being the most grown crop in the country, its production has been unstable over the years as shown in figure 1.

As an example of the fluctuations in the quantity of maize produced in the country, in 2011, maize production in Kenya was estimated to be at 3.7 million metric tons but in 2016 it drastically reduced to an estimated 3.3 million metric tons representing over 11 percent reduction in the level of maize production. This poor performance in maize production in the country has been partly due to climate variations.

To better respond to the effects of variability in climate on agriculture, for instance in 2010 the Kenyan government formed the National Climate Change Response Strategy (NCCRS) that in part was mandated to act on the problems caused by climate variability particularly in the agricultural sector (Republic of Kenya, 2010). Concerning efforts to improve maize production amidst claims of climate variability, in 2016, the Kenyan government initiated a concerted effort to reduce dependency on rain-fed maize production by irrigating an estimated 2,500 hectares of land planted with maize in Galana Kulalu project (Republic of Kenya, 2013).

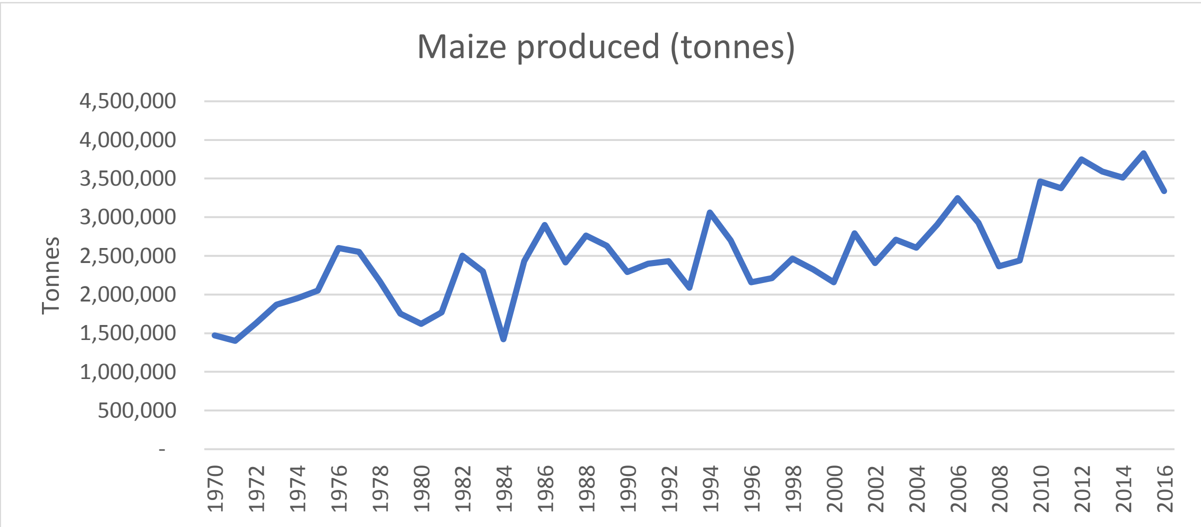

Figure 1: Maize production in Kenya: Source (FAOSTAT)

1.2 Statement of the problem

Most of the agricultural households in Kenya cultivate maize crop for both subsistence and commercial purposes. Data from the Ministry of Agriculture indicates that maize cultivation accounts to over 50 percent of all staples grown in the country. But despite most agricultural households cultivating maize, maize production in the country has been generally non-increasing leading to the rise in maize deficit levels in the country. For example, in 2011, maize production was estimated to be at 3.7 million metric tons but in 2016 it drastically reduced to an estimated 3.3 million metric tons representing over 11 percent reduction in the level of maize production. Further, in 2017, it is approximated that Kenya imported 1.3 million metric tons of maize from 0.8 million metric tons in 2014 marking maize import increment of over 38 percent.

In recent years, the decline in the level of maize produced has been greatly attributed to the rise of unexpected extreme climatic conditions in the country (KIPPRA, 2017). In particular, policymakers in Kenya acknowledged the effects of changes in climate on Kenya's agricultural sector and initiated the NCCRS that in part was mandated to react to the challenges caused by climate change particularly in the agricultural sector and by extension maize production in the country. Notwithstanding the recognition that variability in climate affects agricultural productivity around the policy circles, empirical evidence on how climate variability affects maize production in the country is still scarce.

1.3 Research questions

a) What are the effects of climate change on maize production in Kenya?

b) What is the regional difference on maize production in Kenya?

1.4 Objectives of the study

The main objective of this study was to examine the effects of climate change on maize production in Kenya. Specifically, the study sought to:

a) Establish the effects of climate variability on maize production in Kenya.

b) Examine the regional differences on maize production in Kenya.

c) Draw policy from the study findings

1. 5 Significance of the Study

This study is significant in two main ways. First, there exists scant literature that examines how climate variability affects maize productivity in Kenya. Most studies conducted in Kenya have not exclusively examined the role of climate change on maize productivity from a microeconomic perspective. This in itself presents a knowledge gap that this study attempted to fill. Secondly, this study provides policy insights on the effects of climate change on maize productivity in the country. The insights would help in the formulation of policy that would help reduce the effects of variability in climate in the economy.

1.6 Organisation of the study

The rest of the document is structured as follows: next chapter gives a review of relevant related literature. Literature is subdivided into two sections; theoretical and empirical sections. Chapter three is about the methodology adopted. In particular, theoretical framework, empirical model, data types and sources, as well as estimation strategy, is presented. While chapter four of the study presents study findings and their interpretation, chapter five presents a brief discussion of the findings, conclusion and policy recommendations.

CHAPTER TWO

LITERATURE REVIEW

2 Introduction

This section examines the theoretical approaches that are used to value the climate change variability, the empirical literature on this subject and lastly an overview of the reviewed literature.

2.1 Theoretical Literature

2.1.1 Ricardian approach

The Ricardian approach also called the hedonic approach of valuing the effects of climate variability on agricultural production was developed by Mendelsohn et al. (1994). Mendelsohn et al. argue that the Ricardian approach of analyzing the effects of climate change on agriculture is founded on the Ricardo theory of rent. This theory asserts that value of land (or its rent) reflects its productivity that is based on its inherent and intrinsic characteristics such as soil quality, climatic conditions and land topography (Ricardo, 1817).

The Ricardian approach in particular indicates that the value of land can be equated to the net revenue obtained from the cultivation of crops in the event that the farm owner uses the land in the most efficient manner given the existing environmental conditions and prevailing factor prices and other constraints in the economy (Mendelsohn et al., 1994). Greenstone and Deschenes (2006) argues that in this approach, it is considered that agricultural producers choose to maximize their revenue from crop cultivation given their environmental conditions and land attributes.

Mendelsohn et al. (1994) particularly argues that the Ricardian methodology of assessing the effects of climate change on agricultural production assumes that factor markets particularly the land market is perfectly competitive and that prices of land in different locations in the economy are at their long-run equilibrium levels such that its value can only be attributed to the revenue obtained from the land and existing climatic characteristics. According to Kumar and Parikh (2001), in this approach, therefore, the value obtained from the agricultural production reflects the adjustments and adaptations that farmers make due to the climatic conditions. Mendelsohn et al., (1994) particularly argues that the Ricardian approach captures both the direct and indirect effects of climate changes on the agricultural production in the sense that farmer accounts for the climatic changes through adaptations of their farming activities. It is however important to notice that despite the advantage of the Ricardian approach incorporating farmer's adaptations levels to the changes in the environmental conditions in their farming activities and therefore revenues, the use of the approach in economic analysis relies on the assumption that factor markets function efficiently and that also enforcement of property rights is a priority (Ochieng et al., 2016). This shortcoming can, therefore, be limited in analyzing the effects of variation in climate on crop productivity particularly in a developing country like Kenya.

2.1.2 The production function approach

This approach is always considered as an alternative to the Ricardian approach of valuing climate change in agricultural production. In this approach, the climate variability variables are considered as other inputs of agricultural production and that they enter into agricultural production function directly (Greenstone and Deschenes, 2006; Fisher et al., 2012).

Greenstone and Deschenes (2006) particularly argues that the advantage of the production function approach of valuing the effects of climate change variability on agricultural yield is that it tends to provide a more straightforward and direct measure of a given variation in rainfall or temperature on agricultural productivity. Further, the use of production function approach allows for the estimating the effects of weather on agricultural productivity of a specific crop that are affected by biases that are beyond producers control and the ability, for instance, soil quality (Greenstone and Deschenes, 2006). Despite this approach failing to account for the farmer's adaptations to the climate variability, it doesn't require the assumption of well-functioning factor markets as well as it allows climate variables to directly enter the production function. It is worth noticing that this approach has also been widely used in economic analysis of the effects of climate change on the productivity of crops (Belloumi 2014; Ochieng et al., 2016).

2.2 Empirical Literature

In Kenya, Ochieng et al. (2016) studied the effects of climate variability on agricultural revenue in Kenya. In particular, Ochieng et al., (2016) examined the effects of variation of climate on total crop revenue and tea and maize revenues from small-scale agricultural producers in Kenya. The study finds that climate variability had differential effects on agricultural production since it can raise or decrease crop revenues. In particular, the study found that rise in temperature adversely affects agricultural household crop and maize revenues but has an enhancing effect on tea revenue. In further analyzing the effects of temperature on crop, maize and tea revenue, the study found that temperature has long-term than short-term effects on agricultural production. Concerning the effects of rainfall variability on agricultural production, the study found that rainfall had revenue-enhancing effects on crop and maize revenues but a negative effect on the maize revenues. The study used a fixed-effects model applied to Tegemeo institute data merged with climate data obtained from Kenya Meteorological Services (KMS). Ochieng et al. (2016) used the Ricardian framework in their analysis.

Kabubo-Mariara and Karanja (2007) also studied the effects of climate variability on crop agriculture by using a Ricardian framework. Specifically, the study assessed the effects of climate change on crop revenue. The study found that increases in winter temperatures as well as increased precipitation improved crop revenue. The study combined both agricultural household survey data and climate data which was obtained from the US Department of State and Africa Rainfall and Temperature Evaluation System. Still, in Kenya, Siahi et al. (2018) studied how climate change affects maize productivity from a macroeconomic perspective. By applying the Vector Error Correction Model (VECM), the study established that a rise in the level of rainfall and temperature adversely affect maize productivity in Kenya. The authors used the production function approach for their theoretical framework.

Seo et al. (2005) assessed how variations in climate affects agricultural production in Sri Lanka. This study examined how changes in rainfall and temperatures affected net incomes from tea, corn, coconut, rubber, and rice. The results indicate that precipitation increases the yields for all the crops examined and that revenues for crops increased in the range of 11 to 122 percent. The temperature on the other hand, was found to cause loss of revenue in the range of between 18 to 50 percent. In view of these discoveries, this study, considered temperature and precipitation to be key determinants of maize production in Kenya. In yet another study, Porter and Semenov (2005) looked at the role of climate change on crop production by adopting computer imitations and experimental studies. The study found that a rise in temperature influenced crop processes and hence, there were different impacts on the growth and development of crops. Precipitation was included in this study to capture climatic risk to be able to explain the effect of extreme happenings on the production of crops.

Melissa et al. (2008) looked at the effect of climatic changes on economic activities across the world using data for over 50 years. The study established that a rise in temperatures reduces the growth of the poor economies due to their negative influence on agricultural outputs. Poor countries rely highly on agriculture and therefore, any reduction in agricultural production will impact the economy badly. On the other hand, the study found that variations in the amount of rainfall do not have any substantial effect on the economic growth of poor countries. In another similar study, Kabubo-Mariara and Kabara (2015) examined the effect of variability in climatic conditions on Kenya’s food security by applying fixed and random effect regressions on country-level panel data. They found that variations in temperatures and amounts of precipitation increase food insecurity. Maize, beans, sorghum and millet production were investigated in the study. This study did not consider macroeconomic climate affecting agricultural production for which the current study intends to incorporate.

A study by Wangui (2012) revealed that variations in precipitation and a rise in temperature lead to falling production of coffee in Kiambu, Kenya. The study used Pearson’s correlations. On the other hand, Okoth (2011) found that an increase in mean precipitation increases tea production in Kericho, Kenya while an increase in temperature led to a fall in tea production.

Masud et al. (2014) studied how changes in climate affects rice production in Malaysia. In the study, by controlling for control for the land size, farmers education, and age, the study established that minimal rises in temperature during the main rice planting season increased farmer’s net revenue obtained from the rice production. Further, a rise in the level of rainfall during the off-season had an enhancing effect on the farmer's net revenue per hectare received by the agricultural households. Masud, et al., measured the climate variables by the level of precipitation, rainfall, and temperatures and used the Ricardian framework in their study.

Using cross-sectional data Adamgbe and Ujoh (2013) assessed the effects of average precipitation and temperatures on maize production in South Africa. They established that a rise in both temperature and precipitation increases maize production. The study employed a generalized maximum entropy approach. For the case of Nigeria, Eregha et al. (2014) argued that variation in precipitation, temperature and carbon dioxide concentration led to a reduction in the production of sorghum, cocoa, beans, rice and maize, However, the study found a positive impact of temperature on the production of groundnuts. Precipitation influenced yields for cocoa, beans, cassava, and potatoes positively while rice and groundnuts were influenced negatively.

Zhou and Turvey (2014) examined the effects of variation in climate on agricultural production in Chinese provinces over the period of 32 years. By using the Cobb Douglas production augmented with climate variables, the study established the existence of differential effects of climate change on agricultural production. In particular, the study found that a rise in temperatures levels tends to improve maize production in China. Further, Zhou and Turvey (2014) found that a rise in precipitation levels enhanced maize and wheat production but reduced rice production.

In Bangladesh, Sarker et al. (2012) studied the effects of changes in climate on rice productivity for the period 1972 to 2009. The study found that although climate factors had significant effects on rice production in Bangladesh, the effects were differentiated based on their rice types. Sarker et al. used the OLS and quantile regression techniques in their analysis. In a slightly different study, Zhang et al. (2017) studied how variation in climate affects agriculture for the period 1980 to 2010. In particular, the study examined how humidity and wind speed affect crop yields in China. It was found that wind speed and humidity were critical variables in influencing crop productivity. In particular, the study found that when humidity is excluded from the regression equation, the effect of climate change on crop yield is overreported compared to the underreported values when wind speed is excluded from the equation.

Belloumi (2014) examined the effect of climatic variability on 59 crops by employing econometric models for a 20 year-period data. The study included average monthly temperatures and precipitation between seasons, and changes in mean temperatures and precipitation as explanatory variables. In all explanatory variable, both linear and quadratic terms were added to capture the impact of threshold precipitation and temperatures on crop production. In addition, the study incorporated economic variables in the model. The study established that variations in both temperatures and precipitation significantly influenced crop yields. However, mixed findings were observed with different crop categories. While the study established a positive impact of variation in climate on vegetables, a significant and negative effect was observed for the case of cereals such as maize, rice, tea and coffee. Similarly, Lunduka (2017) employed panel data methods to determine the relationship between variability in the climatic conditions and productivity of cereal crops. The crops examined were: maize, wheat, sorghum, cotton and soybeans. This study observed that precipitation had positive impact on crop yield while temperatures had negative influence on the yields. However, the magnitude of changes in the crop yield dependent on the form of estimated equation.

2.3 Overview of the Literature

The review of the empirical literature suggests that climate variables are important factors in explaining crop production. The studies suggest that use of either the Ricardian approach (Kabubo-Mariara and Karanja, 2007) or the production function approach (Zhou and Turvey, 2014; Ochieng et al., 2016) in valuing the effects of climate variability tend to produce results that climate variables are critical in agricultural production. The same holds for the studies done in Kenya (Ochieng et al., 2016). However, for the Kenyan case, the reviewed literature indicates that no single study has exclusively looked at the role of climate variables on maize production in the country from a microeconomic perspective. This is the knowledge gap that this study attempted to fill since maize is a critical crop in the country where over half the farming households cultivate this crop.

CHAPTER THREE

RESEARCH METHODOLOGY

3.0 Introduction

This chapter gives the theoretical framework that was used to examine the effects of climate change variability, an econometric model that links climate variability to maize production, data source as well as variables definition and measurements and model diagnostic tests.

3.1 Theoretical Framework

The theoretical framework of this study follows the approach by Ochieng et al., (2016) in examining the effects of variations in climate on maize productivity. Considering that maize farmers aim to maximize profit under different climatic conditions, the maize farmer's profits can be stated as:

$$\text{Max } (\pi|z) = \text{P.Y } (X|z) - \text{C}(X|z) \quad (1)$$

Where π denotes farm profits, P is the maize market price, Y is the maize produced by the farmer, Z relates to the vector of climate variability variables i.e rainfall and temperatures, *C* denotes a cost function while X is a set of production inputs such as land, capital, and labour.

Now by assuming that farmers produce maize, we can write the farmers' generalized production function as:

$$Y_i = f(X_i, Z_i) \quad (2)$$

Where Y_i is the maize production of farmer i, X_i is the vector of factors of maize production for example, capital, land and labour, Z_i is a set of climate change variables that in our study it includes temperature and rainfall.

We can, therefore, parameterize equation 2 above as

$$Y_i = AK_i^{\beta_1} F_i^{\beta_2} \ H_i^{\beta_3} \ T_i^{\ \beta_4}{}_i \ R_i^{\ \beta_5}{}_i \qquad (3)$$

Where A captures the effects of technological progress as well as policy-relevant factors, Y_i relating to the farmers' maize production, K_i is the capital employed by farm i, F_i denotes the farm size, H_i denotes human capital measured by the level of household head education, T_i is the temperature, R_i is the rainfall, E_i, G_i and S_i is the household head's age, gender and size. β_s stands for the parameters to be estimated. Parameterizing equation (3) we obtain:

$$In\ Y_i = In\ A + \ \beta_1 InK_i + \beta_2\ F_i \ + \beta_3 H_i + \beta_4 T_i + \beta_5 R_i \qquad (4)$$

Where In stands for the natural logarithm.

3.2 Model Specification

Model specification of the study is drawn from the conceptual framework equation (4) where an error term is introduced. In addition, the study assumes that the error term is normally distributed. Following Ochieng et al. (2016), we can introduce a set of farmer's individual attributes such as age and gender. We can, therefore, write equation 4 as:

$$In\ Y_{it} = \beta_0 + \ \beta_1 InK_{it} + \beta_2 F_{it} + \beta_3 H_{it} + \beta_4\ T_{it} + \beta_5\ R_{it} + \beta_6 A_{it} + \beta_7 S_{it} + \beta_7 G_{it} + \varepsilon_{it} \qquad (5)$$

Where S_{it} is the household size, A_{it} and G_{it} denotes age and gender of hosehold head and ε_i relates to the error term. L is dropped due to the unavailability of data on Kenya's labour force growth rate.

3.3 Variables

Table 3.1 presents variable descriptions

Table 3.1: Variable Measurements and Expected Signs of the Coefficients

Variable	Measurement	Apriori Coefficients
Dependent variable		
Maize production (Y)	Quantity of maize produced. Logarithm of the quantity produced was generated	
Independent variables		
Capital (K)	This was measured by the natural log of total expenditure on capital goods (expenditure on farm productive assets) in kshs.	Positive (Ochieng et al., 2016)
Farm size (fsize)	Was be measured by the logarithm of the area put under maize cultivation (in acres). Natural log was generated.	Uncertain (Zhou and Turvey, 2017)
Human capital development (H)	This was measured by the number of years of household education.	Positive (Ochieng et al., 2016)
Temperature (T)	Temperatures in degrees Celsius corresponding to planting and growing of maize.	Uncertain (Sarker et al., 2012)
Rainfall (R)	Amount of rainfall in millimeters corresponding to planting and growing of maize.	Uncertain (Sarker et al., 2012)
Household head (age)	Age of the household head	Uncertain (Zhang et al., 2017)
Household head gender	This was measured as a dummy variable that equals 1 if the head is male, 0 otherwise.	Positive (Ochieng et al., 2016)
Household size	The number of household members	Positive (Ochieng et al., 2016)

Capital which will be measured by the number of farm productive assets is expected to have a positive sign. Farmers with more assets such ploughs, wheelbarrows, donkeys and other machinery are more productive on their farms since these assets make work easier (Ochieng', 2016). Similarly, human capital measured by the years of the head's education expected to have a positive sign. Education enlightens households on better farming technologies and hence, increase changes of more produce (Siahi et al., 2018). On the other hand, the size of the farm under maize production is anticipated to have a positive or negative sign. A house could have a big farm but which it cannot have the capacity in terms of assets, labor forces, seeds, and other farm resources. This implies that having a big farm does not amount to more production. However, farmers with big lands and with the capacity for farming could produce more.

Both temperature and rainfall are expected to improve or reduce maize production depending on the regional conditions and the stage of plant growth. For instance, the extreme temperature during the earlier stages of maize is expected to influence maize production negatively. Accordingly, too much rain during harvest season is disastrous to maize production. With regard to age, young household heads are more likely to adopter new technology faster than the older one and hence, more maize production. Conversely, the household head is expected to have accumulated more agricultural assets and experience and thus, expected to be more productive. The price of maize was expected to have a positive sign. Famers especially who practice commercial agriculture seek to maximize profits, and therefore, price becomes a motivational factor.

3.4 Data Source

This study used 2004, 2007 and 2010 household survey for Kenya data funded by the USAID and collected by the Tegemeo, Kenya and Michigan State University to measure the agricultural production variables such as maize revenue, size of land under maize cultivation among others. Tegemeo institute collects this data with well-structured and standardized tools across the country apart from Nairobi and Mombasa cities which are largely urban. They use regional clusters to select households, majorly in rural Kenya.

In particular, the data for all the waves contain information on agricultural produce, household size, head of the agricultural household, household size among other covariates used in estimating maize production function. Concerning the climate variability factors, this study used temperature and rainfall annual data obtained from Kenya Meteorological Services (KMS) which was assigned to each wave.

3.5 Estimation Strategy

The study employed panel data methodology to estimate the effect of climate variability of maize production. Panel estimations take care of individual heterogeneity which is very critical (Wooldridge, 2006). In addition, panel methods give more insights based on the fact that it has both time-series and cross-sectional data characteristics. In this study, estimates from System Generalized Methods of Moments (GMM), Fixed Effect (FE) and Random Effect (RE) models as well as the pooled Ordinary Least Squares (OLS) are provided.

CHAPTER FOUR

FINDINGS AND DISCUSSIONS

4.1 Introduction

This chapter outlines the findings of the study and their interpretation. These are presented in two sections. Section one presents descriptive statistics while section two comprises of the econometric analyses.

4.2 Descriptive Statistics

The aim of descriptive statistics was to better understand the variables adopted in the study. Statistics considered here include the mean, standard deviation of the variables used in the study for the years 2004, 2007 and 2010 as shown in table 4.1.

Table 4.1: Descriptive Statistics

Variables	2004		2007		2010	
	M	SD	M	SD	M	SD
Quantity of maize harvested	20.26	44.94	22.73	43.60	17.68	39.70
Value of agricultural assets	177008	312427	237300	400463	299227	638952
Acres of land under maize cultivation	4.906	4.723	4.638	5.088	4.241	4.824
Climate variability (Precipitation)	0.857	0.297	0.817	0.303	0.876	0.326
Climate variability (Temperature)	0.167	0.316	0.159	0.313	0.148	0.321
Age	56.10	13.30	58.28	13.23	60.28	13.16
Household size	5.350	2.364	7.054	2.952	6.858	3.067
Gender	0.822	0.382	0.793	0.405	0.761	0.427
Education	6.98	5.45	6.85	4.73	6.90	4.81

Over the period between 2004 and 2010, the quantity of maize produced by the farmers as measured by the number of 90 Kilograms (kg) has been varying. The descriptive statistics show that, on the average, number of bags of maize harvested rose from an estimated 20 per household in 2004 to 23 bags per household in 2007. However, the statistics show that the proportion of maize harvested on average reduced in 2010 to an estimated 18 from 23 in 2007. The descriptive statistics show an increasing trend in the value of households' assets used in cultivation, rising from an average of Kshs 177,008 in 2004 to Kshs 299, 227 in 2010.

Over the period between 2004 and 2010, the average acreage of land under cultivation for each household has been declining, from 4.9 acres in 2004 to 4.6 and 4.2 acres of land in 2007 and 2010 respectively. This declining trend on the land dedicated to cultivation implies that there has been increased pressure on land over the study period in part due to farm subdivisions.

Concerning climate variability variables, the results show that the trend of precipitation, on average, has been fluctuating over the study period, therefore, corroborating with the fact that precipitation level has been unpredictable. With regards to the temperature variable, although the descriptive statistics shows a rather declining temperature levels, the variability of the variable from its mean as indicated by the standard deviation has been relatively varying further suggesting the unpredictability pattern of the temperature levels in the country.

Concerning the age variable, the descriptive statistics show that, on average, age of the household head has been rising from 56 in 2004 to 60 in 2010. Male headed households were 82.2 percent in 2004 but declined in the years 2007 and 2010 from 79.3 percent to 76.1 percent. The implication of this is the existence of the rising proportion of female-headed households over the study period. Further, the descriptive statistics show that on average, the household's head education remained relatively stable over the period 2004 and 2010 with the average years of schooling being approximately 7 years.

4.3 Econometric Results

4.3.1 Effects of Climate Change on Maize Production

The results of the effects of climate change on maize production are presented in table 4.2. The estimates are based on the panel data estimation techniques that include; System GMM, fixed effects, random effects, and pooled OLS models. Results from these estimation techniques are provided for comparison purposes. We, however, base our interpretation on the estimates obtained from System GMM because the technique tends to provide consistent and robust estimates when there's a potential endogeneity problem in the specified model.

In table 4.2, we observe that climatic variability, in particular temperature variability had significantly influenced maize production in Kenya. In particular, the results of the System GMM indicates that the coefficient of climate variability (temperature) is -2.996 and significant at 1 percent. The implication of this result is that increased temperature unpredictability reduces the quantity of maize produced by the household. Concerning precipitation variability, the results also indicate that the coefficient of climate variability (temperature) is -0.0704 and statistically not significant. Taking together, these results imply that with increased unpredictability of both temperature and precipitation, Kenyan households need to use various adaptation strategies to cushion themselves from the negative effects of climate variability to increase maize yields. Similar findings have also been established in some papers done in Kenya. For instance, Ochieng et al. (2016) through the use of a fixed-effects model found that climate variability in had negative effects on maize production and consequently revenues. In yet another study in Kenya, although from a macroeconomic perspective, Siahi et al. (2018) found that an increase in the level of rainfall and temperature variability adversely affected maize productivity in Kenya.

Concerning the control variables in the model, it is observed that increases in the value of household's assets used in cultivation significantly increase maize production in Kenya. In particular, the results establish that a 1 percent increase in the value of agricultural assets owned by the household increases the quantity of maize harvested by households by approximately 0.488 percent. This result implies that with ownership of farm assets such as plough, wheelbarrows, donkeys and other machinery, a farmer tends to harvest more maize. The results also suggest that additional land put under production reduces maize production. More specifically, the results show that an additional acreage of land under maize cultivation reduces the quantity of maize harvested by 0.244 percent. One possible explanation for this finding is that that labour market inadequacies could cause the negative relationship between farm size and productivity (Ali and Deininger, 2015) as well as statistical artefact caused by measurement error in recording agricultural produce (see for example, Gourlay, Kilic and Lobell, 2017).

With regards to the age of the household head, the results indicate that maize production increases with the aging of the household head. The possible explanation for this result is that older household heads can be more productive compared to young farmers due to experience gained from farming for a long period. On the size of the household, the results indicate that maize production significantly improves with the size of the household. An additional member in the household increases the quantity of maize harvested by an estimated 0.0918 percent.

Table 4.2: Effects of Climate Variability on Maize Production

	System GMM	Fixed Effects	Random Effects	Pooled OLS
Log value of agricultural assets	0.488*	0.0498**	0.0974***	0.109***
	(0.251)	(0.0221)	(0.0156)	(0.0146)
Acres of land under maize cultivation	-0.244***	0.0541***	0.0771***	0.0868***
	(0.0908)	(0.00484)	(0.00363)	(0.00344)
Climate variability (Precipitation)	-0.0704	0.217	-0.510***	-0.612***
	(0.179)	(0.136)	(0.0648)	(0.0547)
Climate variability (Temperature)	-2.996***	3.093***	-0.194***	-0.152***
	(0.637)	(1.145)	(0.0680)	(0.0528)
Age	0.0288**	0.000321	-0.00279*	-0.00337**
	(0.0117)	(0.00372)	(0.00162)	(0.00134)
Household size	0.0918***	0.0100	0.0282***	0.0326***
	(0.0337)	(0.00822)	(0.00614)	(0.00580)
Gender	0.517***	0.0966	0.123**	0.113***
	(0.199)	(0.0925)	(0.0489)	(0.0414)
Education	0.00541	0.0100	0.00988**	0.00805**
	(0.0243)	(0.00710)	(0.00438)	(0.00386)
Constant	-3.993	3,123	1.119***	1.048***
	(2.585)	1,041	(0.182)	(0.158)
AR (1)	0.00			
Hansen test for overidentification	0.384			
Observations	3,123	3,123	3,123	3,123

*Notes: (i) Log of quantity of maize harvested is the dependent variable (ii) instruments used in GMM estimation are: logarithms of the quantity of maize, the value of agricultural assets, acres of land under cultivation, climate variability variables, household size and head education. (iii) Exogenous variables considered in GMM estimation are age and gender of the household head (iv) Standard errors in brackets (v) ***, **, & * show significance levels at 1%,5% and 10% respectively (vi) controlled for the year variable (vii) We did not include AR(2) because the model in second differences has only 3 observation per household and as such we do not test for second order autocorrelation in the disturbances.*

Concerning the gender of the household head, the results indicate the existence of gender differences in maize production in Kenya. In particular, the results establish that households headed by male produce 0.517 percent more bags of maize in comparison to those headed by females. A possible explanation for this result tends to be two-fold. One, female-owned farms tend to be constrained in access, control, and mobilization of labor to work on their farms due to several factors that include institutional, such as societal norms and culture. Second, women tend to lack farming support and technologies such as inorganic fertilizer, improved variety of seeds, pesticides, and mechanical power and therefore are inclined to grow more subsistence crops. On the education, the results establish that an increase in the education level of the household head is associated with a reduction in the quantity of maize produced. The result could be explained by the fact that education obtained by household heads might not be quite applicable in improving maize production and that specific and targeted education and training on maize production could improve yields in Kenya.

4.3.2 Regional Differences on Maize Production

Table 4.3 present the estimates of the regional difference on maize production in Kenya based on the System GMM regression technique. In this regression, we examined the effects of climate change on maize production in the former larger provinces, i.e. Coast, Eastern, Nyanza, Western, Central, and Rift Valley. North Eastern Province is excluded because maize is rarely produced in this region due to unfavorable climatic conditions.

Table 4.3: Regional Difference on Maize Production

	System GMM
Log value of agricultural assets	0.373
	(0.307)
Total acres of land under maize cultivation	-0.216**
	(0.0934)
Climate variability (Precipitation)	-0.119
	(0.241)
Climate variability (Temperature)	-2.556***
	(0.962)
Age	0.0304**
	(0.0150)
Household size	0.0584**
	(0.0298)
Gender	0.410*
	(0.241)
Education	0.0114
	(0.0221)
Coast Province	1.126***

	(0.349)
Eastern Province	2.211***
	(0.650)
Nyanza Province	0.742**
	(0.327)
Western Province	1.475***
	(0.339)
Rift Valley Province	1.574***
	(0.246)
Constant	-4.040
	(3.258)
AR (1)	0.00
Hansen test for overidentification	0.143
Observations	3,123

*Notes: (i) Log of quantity of maize harvested is the dependent variable (ii) instruments used in GMM estimation are: logarithms of the quantity of maize, the value of agricultural assets, acres of land under cultivation, climate variability variables, household size and head education (iii) Exogenous variables considered in GMM estimation are age and gender of the household head (iv) Standard errors in brackets (v) ***, **, & * denote significance levels at 1%,5%, and 10% respectively (vi) Central province is the reference category for regions (v) controlled for the year variable (vi) we did not include AR(2) because the model in second differences has only 3 observation per household and as such we do not test for second order autocorrelation in the disturbances (Vii) Central province is the regional reference category*

The regression results of the regional differential effects on maize production indicate the existence of significant regional variations on the maize production. In particular, the results indicate that maize farmers in the Coastal, Eastern, Nyanza, and Rift Valley Provinces produce more maize as compared to those from Central province.

CHAPTER FIVE

SUMMARY, CONCLUSION, AND RECOMMENDATIONS

5.1 Introduction

This chapter makes a summary and conclusion of the study based on the study objectives. In addition, the study suggests policy recommendations from study findings.

5.2 Summary and conclusion

The main objective of this paper was to analyze the effect of climate change on maize production in Kenya. Specifically, the study sought to examine the effect of variability in temperature and rainfall on maize production in Kenya as well as the regional differences on maize production in Kenya.

This study used the Tegemeo household survey dataset for the period 2004, 2007 and 2010 for the maize production variables such as the quantity of maize produced, size of land under maize cultivation among others. For the climate variability factors, this study used temperature and rainfall annual data obtained from Kenya Meteorological Services (KMS) which was assigned to each wave. The study applied panel data estimation techniques; system GMM, fixed effects, random effects and Pooled OLS models on 2004, 2007 and 2010 household surveys. For interpretation and evaluation of the results, the study relied on the system GMM estimates because of its ability to mitigate endogeneity in the regression.

With regards to the effects of climate variability on maize production, the estimated results established that variability in temperature during the period under study had a negative effect on maize production in Kenya. Further, the results found that increases in agricultural assets, age of the household head and household size significantly increased household maize production. Further, male-headed households were able to produce more maize in comparison to female-headed households. The results established that household maize production reduced with acreage devoted to maize production.

Regarding the regional differences on maize production, the study reported differential effects. The estimates show that maize farmers in the Coastal, Eastern, Nyanza, and Rift Valley Provinces produce more maize as compared to those from Central province.

5.3 Recommendation

From the study, it is observed that climate variability significantly reduces the quantity of maize produced in Kenya, with the effect being larger in non-traditional maize growing regions of Kenya. The implication of this finding is that with increased unpredictability of both temperature and precipitation, Kenyan households should need to undertake various adaptation strategies to cushion themselves from the negative effects of climate variability in order to increase maize yields. Further, the Kenyan government should also adopt policy interventions that help mitigate the effects of global warming. Practices such as wanton destruction of forests and increased release of harmful chemicals in the atmosphere should be curbed at all costs.

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